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THE BEHAVIOR OF A METALITE PLATE WHEN SUBJECTED TO UNIFORMLY DISTRIBUTED LOADS ACTING IN THE PLANE OF THE PLATE

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August 31,
1949

A Thesis Submitted to the Faculty of the Graduate School
in Partial Fulfillment of the Requirements for the
Degree of Master of Science

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PREFACE

As far as the writer knows biaxial, uniformly distributed edge loading of simply supported sandwich plates has not been widely achieved in testing programs. It is intended that the method, with results, enumerated herein is not a realization of the goal but progress in that direction.

The writer takes this opportunity to acknowledge the supervision and advice of his thesis advisor, Professor Joseph A. Wise of the Institute of Technology, University of Minnesota, the assistance of Second Lieutenants Hans Knudsen and Paul Kjolseth, Norwegian Air Force in the laboratory work, and Mr. W. A. Pitman and others of the Chance Vought Aircraft Division of the United Aircraft Corporation.

ABSTRACT

The design of an arrangement for applying uniformly distributed biaxial loads to a plate when the plate edges are simply supported is presented; the behavior of a sandwich plate (Metalite) when it was subjected to this type of load and edge conditions is presented. The method of transformed sections is utilized to predict the plate critical load for the sandwich plate (Metalite); a comparison is made between the value predicted by this method and that predicted from laboratory testing with the loading arrangement. Principal strains and principal stresses at selected points on the surface of the plate are presented; deflections of these selected points also are included.

DEFINITION OF PROBLEM

By means of a testing apparatus and procedure it was desired to observe the behavior of a flat Metalite plate with the edges of the plate simply supported when the plate was subjected to uniformly distributed loads acting biaxially in the plane of the plate. From these observations it was intended that the plate critical load could be established for the edge and load conditions specified. Thus, the problem was two fold; (1) to obtain the desired edge conditions for the plate; (2) to observe the behavior of the plate.

LIMITATIONS OF PROBLEM

(a) For the test specimen

It was assumed that the test specimen was flat prior to test. This condition did not prevail because the plate had an initial curvature in each of the two edge directions; in magnitude it was in the order of one-tenth of an inch at the center of the plate. It was assumed that the test specimen was representative of any Metalite plate fabricated to the same over-all and component parts dimensions as the plate tested.

(b) For the testing apparatus

As the apparatus originally was designed the biaxial loads applied to the plate were to be distributed uniformly along the edges of the plate through a system of toothed blocks. The teeth were incorporated in the blocks to relieve the edge restrictions to plate contraction imposed by the action of biaxial loading transmitted by a continuous surface. In the testing of the plate it was necessary to sacrifice the principal of the toothed blocks in order to hold the plate in position when it was subjected to loads. The modification of the testing apparatus which was required to hold the plate in position also restricted the available amount of edge rotation of the plate; the restriction made it impossible to apply sufficient load to realize experimentally the plate critical load. The assumption that the edges of the plate

were simply supported was not realized exactly; the center lines of edge rotations were in the mid-plane of the plate removed approximately two and thirteen-sixteenths inches from the edges.

CONCLUSIONS

(1) That for edge and load conditions as specified (simply supported and uniformly distributed, respectively) the plate critical load for a Metalite plate of the size and dimensions tested as determined from an analysis of the deflection data is ten thousand two hundred pounds (two hundred ninety pounds per linear inch).

(2) That the plate critical load as predicted by the method of transformed section is eight thousand five hundred and eighty-five pounds (two hundred forty-five pounds per linear inch).

(3) That the difference between these predicted plate critical loads is due in part to the type of analysis of the deflection data (assuming that the deflection is infinite at the plate critical load).

(4) That duplications of this testing should be performed on similar plates to establish the plate critical load.

(5) That the testing apparatus should be modified further or in a different manner in order that the edge conditions assumed and sought may be more nearly realized.

INTRODUCTION

To explain the fabrication of Metalite, the following is quoted from an article "Experiences With Sandwich Materials in Air Frames" by H. B. Gibbons and E. MacDonough of Chance Vought Aircraft presented at a symposium on "The Theory and Practice of Sandwich Construction in Aircraft" at the sixteenth annual meeting of the Institute of the Aeronautical Sciences in New York City during 26-29 January 1948:

"The manufacture of Metalite is essentially a molding operation which involves a series of relatively simple processes. The sheet metal parts are first cut to shape, then thoroughly cleaned, masked for spraying, and sprayed with Cycleweld adhesive. They are then cured for one-half hour at 325 degrees Fahrenheit. The end grain core is produced by gluing a number of balsa planks into bolts about two feet by four feet in cross-section and by cutting slices slightly greater than the required core thickness from these bolts with a band saw. To form the required panel size, the slices are further edge-glued together and trimmed. The panel is sanded to the desired thickness on a drum sander and routed where necessary for internal doublers and splice plates. The wood core is then sized with a very light application of a radically different type of resin and no further adhesive applied. The secondary adhesive is applied to the areas of the metal

parts that are coated with Cycleweld. The metal parts are then assembled with the wood core on a mold of the required contour. The assembly is covered with a light rubber blanket, which is sealed to the mold, and cured in an autoclave for one hour at 230 degrees Fahrenheit and sixty pounds per square inch."

TEST EQUIPMENT

(1) Olsen compression-load testing machine. (provided the vertical component of the biaxial loads)

(2) Load distributing arrangement (see Appendix A). (also included provision for horizontal component of biaxial loads)

(3) SR-4 Baldwin Southwark Strain Indicator.

(4) Test specimen (Metalite plate) with properly attached strain gages (rosettes).

(5) Ames deflection dials.

TEST PROCEDURE

(1) Calibrate the tension rods in a tensile testing machine for a load versus strain curve. (established a means for determining the horizontal load applied to the test specimen)

(2) Align the frame of the load distributing apparatus on supports on the bed of the Olsen compression-load testing machine.

(3) Install the test specimen, load distributing bars and blocks in the frame in a manner such that the applied loads will act in the plane of the plate (assuming the plate is flat).

(4) Wire all strain gages to the selector box. (facilitated the observing and recording of strain indicator readings)

(5) Secure the mounts for the Ames dials to the frame and attach the dials to the mounts.

(6) Record the no-load strain indicator reading of all the strain gages and zero the Ames dials.

(7) Apply biaxial loads in desired increments, record the strain gage and Ames dial readings at each increment.

TEST SPECIMEN

Type	Metalite plate.
Size:	Thirty-five inches square.
Core:	Nine pounds per cubic foot balsa wood. (tolerance of plus one-half pound, minus nothing). Thirty-six hundredths of an inch thick.
Faces:	24S-T3 Alclad aluminum alloy, grain on opposite faces parallel. Sixteen thousandths of an inch thick.
Adhesive:	Redux.
Composition:	Figure 2.

PRESENTATION OF OBSERVATIONS

The four strain gage rosettes on each face of the plate were mounted opposite each other in the following manner (Figure 3):

I opposite V
II opposite VI
III opposite VII
IV opposite VIII

In addition, on the east face of the plate rosettes II and IV were symmetrically located; a similar relationship existed between rosettes VI and VIII on the west face of the plate.

In Table I is presented the strain indicator readings reduced to a zero reading at no-load conditions. In Tables 2, 3, 4, and 5, which include the maximum and minimum strains and stresses as determined from the solution of the strain gage rosettes, the angles listed are those which are included between the line of maximum strain or stress and a horizontal axis originating at the center of the rosette. For the rosettes on the east face of the plate the angle is measured positively in a counterclockwise direction from the north end of the horizontal axis, and positively in a clockwise direction from the north end of the horizontal axis for the rosettes on the west face of the plate. This convention of sign notation and selection of references facilitates comparisons between values on opposite faces of the plate at the four locations of the rosettes.

In Figures 6, 7, 8, and 9 the difference in maximum principal stresses between faces at the location of each of the rosettes is shown graphically.

In Figure 10 is a graphical presentation of the variation in the direction of the maximum principal strains and stresses at each of the rosette locations.

In Table 6 is contained the amounts of plate deflection at the various increments of edge loads; the locations of the deflections with respect to the plate is shown in Figure 4; this deflection data is shown graphically in Figure 5.

DISCUSSION OF DATA

At all four of the locations on the plate at which strains were measured and the principal stresses determined, the stress on the concave side (east face) of the plate was consistently greater in magnitude than on the convex side. As the plate critical load was approached these stresses tended to become more nearly equal in magnitude (Figures 6 through 9). The plot in Figure 5 of the deflection of the center of the plate was analyzed for a best-fitting curve; several expressions were tried and a secant function selected on the assumptions that the slope of the curve should be infinite at the plate critical load (the deflection also infinite) and the curve should indicate no deflection at the origin of recorded deflections. This best-fitting secant curve was determined

by the method of the least sum of the squares of the differences between theoretical and actual values of deflections. The function so determined is of the form

$$\delta_n = A\,q_n \text{ secant } \left(\frac{\pi}{2} q_n\right)$$

where delta_n is equal to the deflection at the n th value of load,

A is equal to a constant to be determined,

q_n is equal to the ratio of $\frac{P_n}{P_{cr}}$,

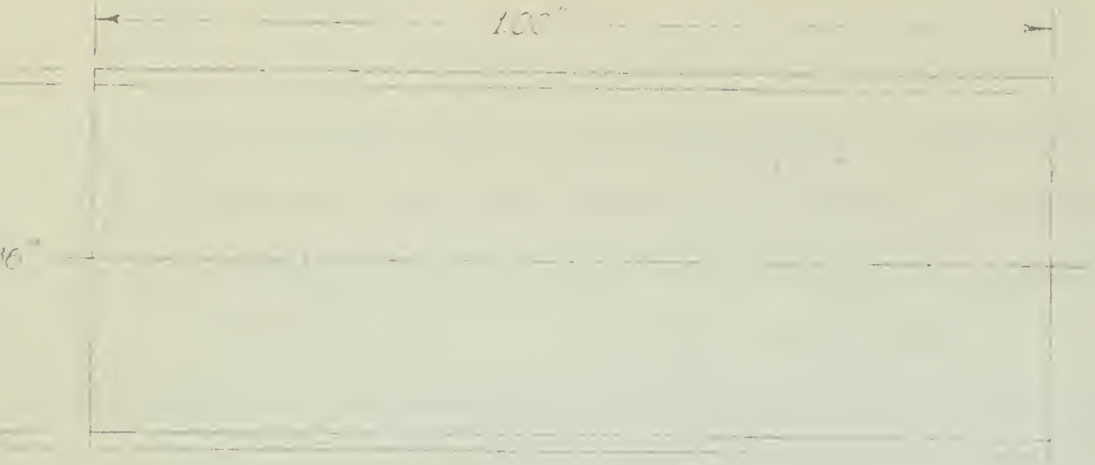
P_n is equal to the load less 1000 at the n th value of load,

P_{cr} is equal to the plate critical load less 1000.

For the deflections as observed at the center of the plate, values of A equal to 0.7678 and P_{cr} equal to 9200 yields the best-fitting curve. Therefore, the plate critical load (at which the deflection is infinite) by this method of extrapolation is ten thousand two hundred pounds. At an edge load of eight thousand five hundred eighty-five pounds the deflection would be two and thirty-two hundredths inches.

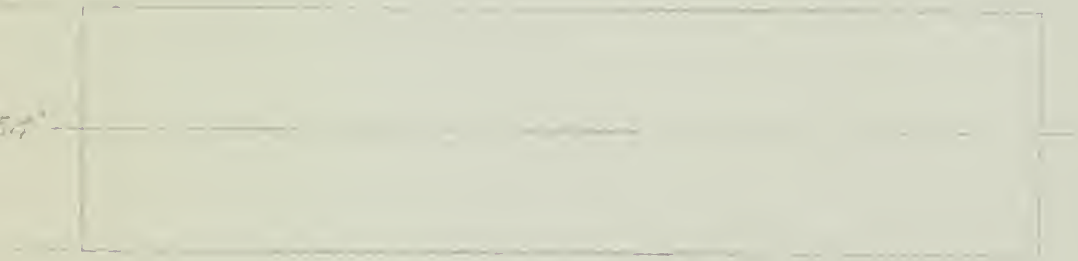
FIGURE 1

TRANSFORMED SECTION



Member Section

Transformed Section



Equivalent Section

ANALYTICAL CONSIDERATION

For a rectangular, simply supported plate subjected to biaxial uniformly distributed forces the critical forces, as determined by assuming the plate deflects in the form of a double sine series and by equating the internal and external energy, are:[1]

$$P_x m^2 b^2 + P_y n^2 a^2 = \frac{t^3}{12} \cdot \frac{E}{1-\mu^2} \cdot \pi^2 \cdot \frac{(m^2 b^2 + n^2 a^2)^2}{a^2 b^2}$$

By the method of transformed sections, the thickness of the web in the transformed section is equal to the ratio of the moduli of elasticity of the two materials in the compound sections[2]. If it is assumed that the modulus of elasticity for the fact material is 10.3 x 10^6 pounds per square inch and for the core material is 0.5665 x 10^6 pounds per square inch[3], the ratio of the core modulus to face modulus is 0.055, which is the thickness of the web in the transformed section.

The moment of inertia of this transformed section about its center line is 0.00134553 inches^4. The thickness of the equivalent plate is then the cube root of 12 x 0.00134553 or 0.254 inches (Figure 1). Substituting this value in the above equation and assuming mu equal to 0.3, P_x equal to P_y, n equal to m equal to unity, and a equal to b equal to 35, the plate critical load is two

---

Subscripts 1, 2, 3, refer to references.

hundred forty-five pounds per inch or eight thousand five hundred eighty-five pounds per edge.

If, in this calculation, a value of 10 x 10^6 pounds per square inch had been assumed for the modulus of elasticity of the face material, the final result would have been two hundred forty pounds per inch or eight thousand four hundred pounds per edge.

RECOMMENDATIONS

(1) That the testing apparatus be modified to allow a greater amount of rotation of edges of the test plate. This can be accomplished by reducing the size of the plate positioning blocks, or increasing the space between the angle frames, or cutting plate positioning slots into the teeth of the toothed loading blocks. These possibilities are listed in order of increasing difficulty; although the third one would be most difficult, it would produce the most desirable final result.

(2) That a series of tests be conducted on similar plates to verify the results of this project and to achieve the determination of a plate critical load by laboratory testing.

(3) That tests be conducted on plates of homogeneous material with dimensions corresponding to those obtained by the method of transformed section for use in comparative analysis.

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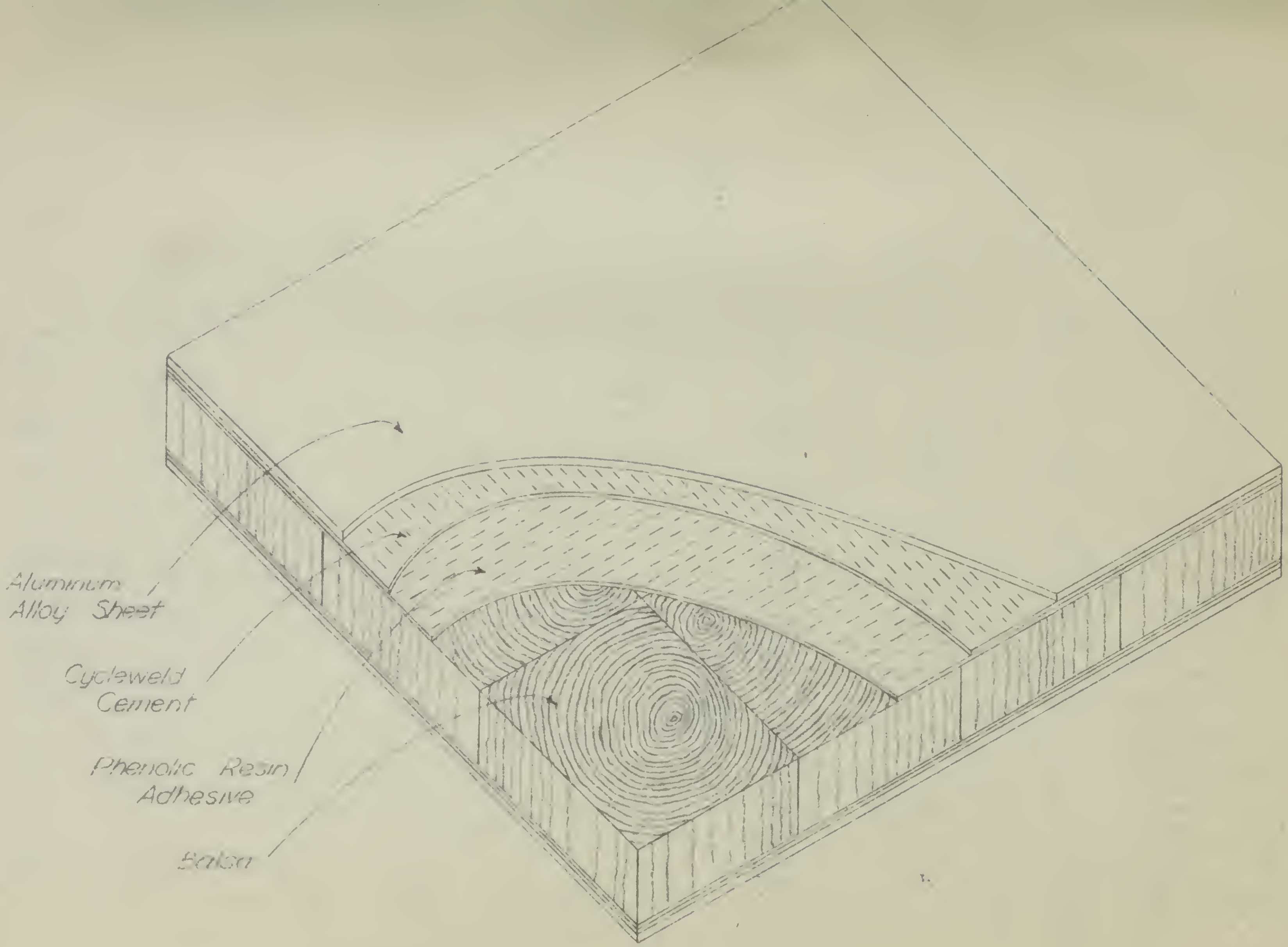
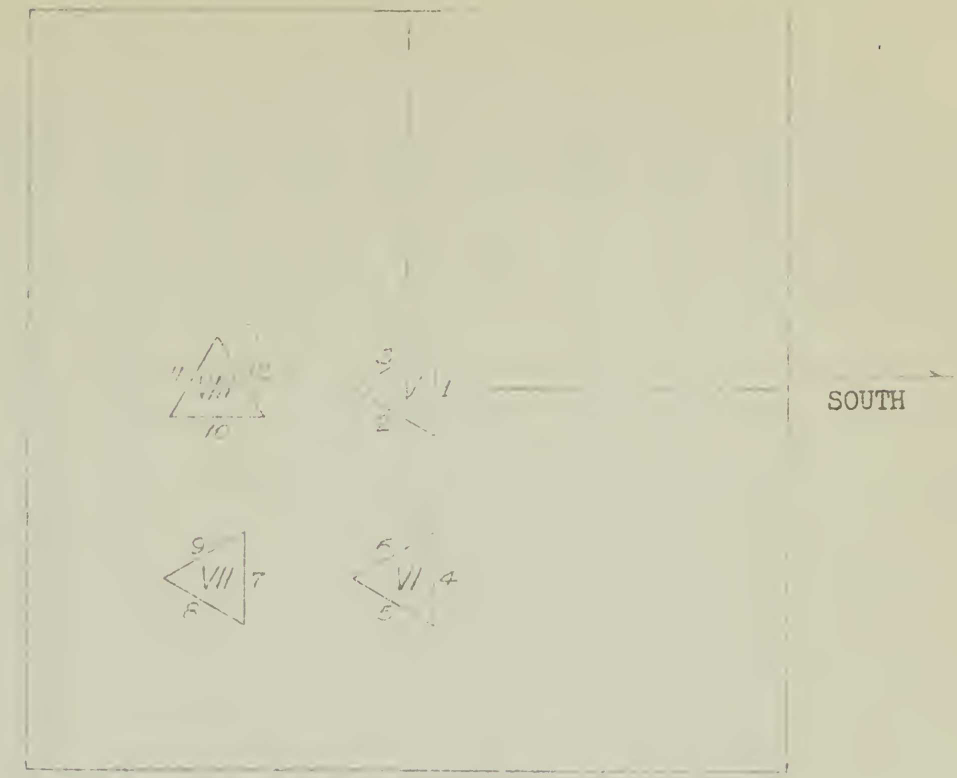


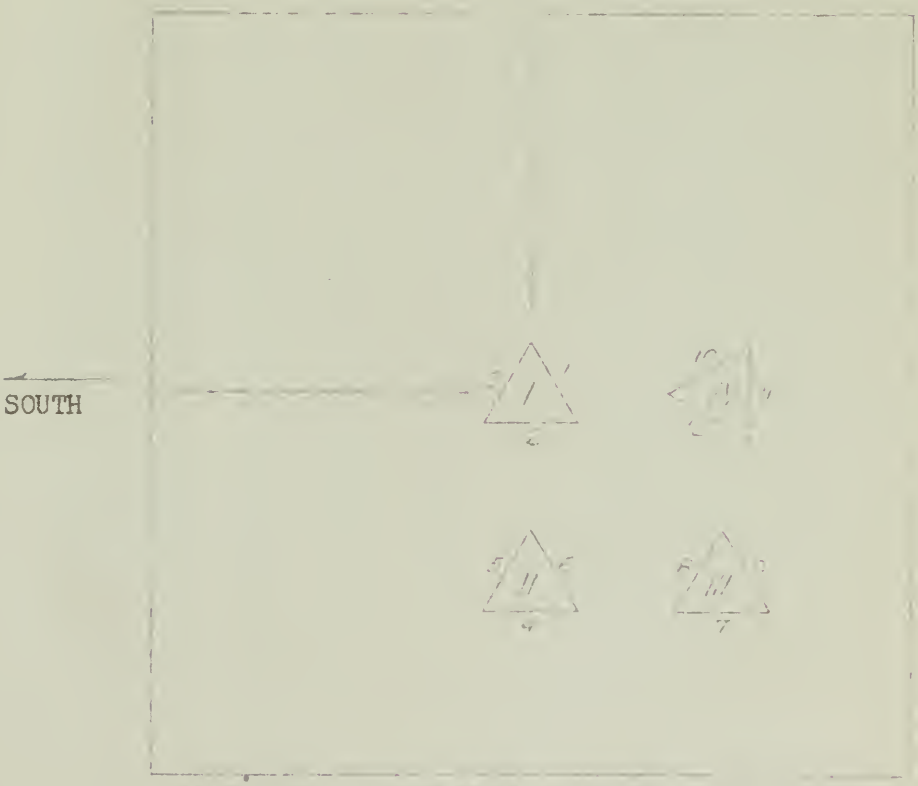
Figure 2.
Section of Metalite Sandwich

FIGURE 3

ARRANGEMENT OF STRAIN GAGES ON METALITE PLATE



WEST SIDE AS SEEN WHEN OBSERVED FROM THE WEST



EAST SIDE AS SEEN WHEN OBSERVED FROM THE EAST

TABLE 1

STRAIN GAGE DATA

	ROSETTE I			ROSETTE II			ROSETTE III			ROSETTE IV		
EDGE LOAD	GAGE 1E	GAGE 2E	GAGE 3E	GAGE 4E	GAGE 5E	GAGE 6E	GAGE 7E	GAGE 8E	GAGE 9E	GAGE 10 E	GAGE 11 E	GAGE 12 E
0000	000	000	000	000	000	000	000	000	000	000	000	000
1000	-28	-120	-40	-90	-53	-96	-95	-50	-31	-66	-23	-110
2000	-178	-229	-149	-183	-155	-200	-194	-153	-121	-162	-117	-230
3000	-338	-387	-282	-323	-280	-315	-326	-292	-191	-286	-228	-374
4000	-428	-530	-420	-453	-403	-428	-459	-458	-251	-410	-357	-526
4400	-538	-596	-473	-516	-460	-476	-520	-542	-256	-462	-417	-592
4800	-528	-640	-520	-563	-498	-508	-567	-611	-291	-510	-470	-638
5200	-647	-711	-587	-641	-553	-578	-620	-711	-309	-580	-540	-730
6000	-773	-839	-697	-785	-671	-692	-787	-921	-343	-717	-682	-885
7000	-900	-980	-779	-971	-808	-845	-1040	-1258	-387	-917	-857	-1138

	ROSETTE V			ROSETTE VI			ROSETTE VII			ROSETTE VIII		
EDGE LOAD	GAGE 1W	GAGE 2W	GAGE 3W	GAGE 4W	GAGE 5W	GAGE 6W	GAGE 7W	GAGE 8W	GAGE 9W	GAGE 10 W	GAGE 11 W	GAGE 12 W
0000	000	000	000	000	000	000	000	000	000	000	000	000
1000	-25	-9	25	-19	-10	22	-40	13	43	19	-8	-77
2000	-15	8	40	3	2	27	-24	50	-22	28	-7	-57
3000	79	65	105	82	32	57	37	80	-32	67	29	3
4000	190	166	208	176	81	105	97	140	-21	146	73	86
4400	258	223	267	226	110	137	132	177	5	197	114	136
4800	327	284	330	279	143	174	170	228	13	252	149	183
5200	420	363	420	366	192	222	220	258	50	331	212	253
6000	642	549	620	568	302	332	342	370	150	526	342	405
7000	970	822	929	912	462	508	559	550	380	874	575	634

TABLE 2

PRINCIPAL STRAINS
PRINCIPAL STRESSES
REFERENCE ANGLE
ROSETTE I

BI-AXIAL EDGE LOAD	MIN STRAIN	MAX STRAIN	ANGLE TO MIN STRAIN	ANGLE TO MAX STRAIN	MIN STRESS	MAX STRESS
1000	-5.1	-120.3	183 25	93 25	-465	-1380
2000	-138.7	-231.9	169 33	79 33	-2360	-3100
3000	-275.1	-396.3	164 04	74 04	-4460	-5420
4000	-388.5	-530.1	178 10	88 10	-6200	-7330
4400	-464.7	-606.7	164 05	74 05	-7320	-8450
4800	-485.3	-640.1	178 20	88 20	-7665	-8900
5200	-576.5	-720.1	165 30	75 30	-8970	-10100
6000	-687.7	-851.7	163 50	73 50	-10670	-11980
7000	-769.0	-1003.2	161 39	71 39	-12120	-13970

ROSETTE V

BI-AXIAL ADGE LOAD	MIN STRAIN	MAX STRAIN	ANGLE TO MIN STRAIN	ANGLE TO MAX STRAIN	MIN STRESS	MAX STRESS
1000	-32.4	26.4	69 10	159 10	-277	189
2000	-20.8	42.8	72 20	162 20	-90	414
3000	59.6	106.4	49 55	139 55	1030	1412
4000	163.7	212.3	42 57	132 57	2577	2960
4400	222.5	276.2	35 38	125 38	3490	3880
4800	284.0	343.4	31 40	121 40	4380	4850
5200	363.0	439.0	30 00	120 00	5600	6205
6000	547.6	659.8	23 30	113 30	8450	9335
7000	818.9	995.1	22 15	112 15	12650	14060

TABLE 3

PRINCIPAL STRAINS
PRINCIPAL STRESSES
REFERENCE ANGLE

ROSETTE II

BI-AXIAL EDGE LOAD	MIN STRAIN	MAX STRAIN	ANGLE TO MIN STRAIN	ANGLE TO MAX STRAIN	MIN STRESS	MAX STRESS
1000	-52.9	-113.1	146 42	56 42	-984	-1458
2000	-153.3	-205.3	138 55	48 55	-2432	-2960
3000	-279.6	-332.4	155 03	65 03	-4290	-4710
4000	-399.2	-456.9	165 00	75 00	-6060	-6530
4400	-450.7	-517.3	171 57	81 57	-6860	-7380
4800	-482.7	-563.3	175 54	85 54	-7385	-8010
5200	-576.5	-720.1	172 00	82 00	-8280	-9100
6000	-646.0	-786.0	175 00	85 00	-9970	-11100
7000	-775.6	-973.8	172 40	82 40	-12070	-13650

ROSETTE VI

BI-AXIAL EDGE LOAD	MIN STRAIN	MAX STRAIN	ANGLE TO MIN STRAIN	ANGLE TO MAX STRAIN	MIN STRESS	MAX STRESS
1000	-27.2	22.5	66 02	156 02	-231	162
2000	-6.0	27.4	59 02	149 02	25	290
3000	28.2	85.9	15 00	105 00	610	1067
4000	63.7	177.7	7 02	97 02	1324	1548
4400	87.7	227.7	6 25	96 25	1766	2840
4800	116.7	280.7	6 15	96 15	2264	3528
5200	153.0	367.0	4 39	94 39	2978	4620
6000	232.7	568.7	2 55	92 55	4560	7145
7000	341.5	913.1	2 45	92 45	6965	11350

TABLE 4

PRINCIPAL STRAINS
PRINCIPAL STRESSES
REFERENCE ANGLE

ROSETTE III

BI-AXIAL EDGE LOAD	MIN STRAIN	MAX STRAIN	ANGLE TO MIN STRAIN	ANGLE TO MAX STRAIN	MIN STRESS	MAX STRESS
1000	-20.8	-96.6	8 22	98 22	-676	-1162
2000	-113.8	-198.3	13 00	103 00	-1960	-2632
3000	-188.7	-350.7	22 57	112 57	-3330	-4615
4000	-251.0	-527.7	29 53	119 53	-4630	-6820
4400	-255.3	-623.3	31 58	121 58	-5000	-7920
4800	-289.7	-689.7	33 38	123 38	-5625	-8795
5200	-303.2	-790.2	36 13	126 13	-6125	-9980
6000	-334.5	-1022.7	36 24	126 24	-7255	-12720
7000	-373.0	-1417.0	36 58	126 58	-9040	-17300

ROSETTE VII

BI-AXIAL EDGE LOAD	MIN STRAIN	MAX STRAIN	ANGLE TO MIN STRAIN	ANGLE TO MAX STRAIN	MIN STRESS	MAX STRESS
1000	-43.3	53.9	79 30	-10 30	-307	463
2000	-47.4	50.0	113 09	23 09	-367	405
3000	-36.9	93.5	138 48	48 48	-100	932
4000	-24.2	168.2	142 34	52 34	297	1820
4400	-0.1	202.7	141 15	51 15	687	2292
4800	8.7	265.3	142 30	52 30	998	3030
5200	48.3	303.7	145 05	55 05	1578	3600
6000	149.3	425.3	146 25	56 25	3135	5320
7000	380.0	612.6	148 49	58 49	6370	8235

TABLE 5

PRINCIPAL STRAINS
PRINCIPAL STRESSES
REFERENCE ANGLE

ROSETTE IV

BI-AXIAL EDGE LOAD	MIN STRAIN	MAX STRAIN	ANGLE TO MIN STRAIN	ANGLE TO MAX STRAIN	MIN STRESS	MAX STRESS
1000	-16.1	-116.5	164 48	74 48	-578	-1376
2000	-104.1	-235.3	161 40	71 40	-1977	-3020
3000	-211.2	-380.8	161 35	71 35	-3680	-5030
4000	-331.4	-530.6	158 54	68 54	-5555	-7140
4400	-385.5	-595.1	157 13	67 13	-6380	-8055
4800	-438.1	-640.5	156 35	66 35	-7135	-8750
5200	-501.2	-732.2	155 42	65 42	-8160	-10000
6000	-636.3	-886.3	154 33	64 33	-10200	-12200
7000	-799.9	-1141.5	155 48	65 48	-12930	-15650

ROSETTE VIII

BI-AXIAL EDGE LOAD	MIN STRAIN	MAX STRAIN	ANGLE TO MIN STRAIN	ANGLE TO MAX STRAIN	MIN STRESS	MAX STRESS
1000	-79.1	35.1	63 20	-26 40	-776	129
2000	-58.9	37.6	71 40	-18 20	-540	226
3000	4.6	61.4	78 05	-11 55	260	710
4000	56.8	146.6	94 48	4 48	1140	1852
4400	99.4	198.6	97 25	7 25	1800	2588
4800	137.2	252.2	99 28	9 28	2410	3320
5200	195.5	335.1	99 56	9 56	3355	4455
6000	316.5	532.1	99 52	9 52	5505	7100
7000	497.3	1191.3	102 12	12 12	9680	14620

TABLE 6

EDGE LOAD IN POUNDS	DEFLECTION IN THOUSANDTHS OF AN INCH					
	A	B	C	D	E	F
1000	000	000	000	000	000	000
2000	12	14	16	39	42	51
3000	30	40	55	110	124	148
4000	47	65	80	196	224	270
4400	58	80	96	240	277	333
4800	66	92	111	280	323	387
5200	80	112	135	340	394	470
5600	95	130	157	396	456	544
6000	118	157	186	476	544	647
6200	132	175	205	523	598	707
6400	142	188	220	559	637	748
6600	156	212	250	622	712	830
7000	181	250	291	---	814	940

FIGURE 4

EAST SIDE AS SEEN WHEN OBSERVED FROM THE EAST

FIGURE 5

PLATE DEFLECTION

VERSUS

BIAXIAL EDGE LOAD

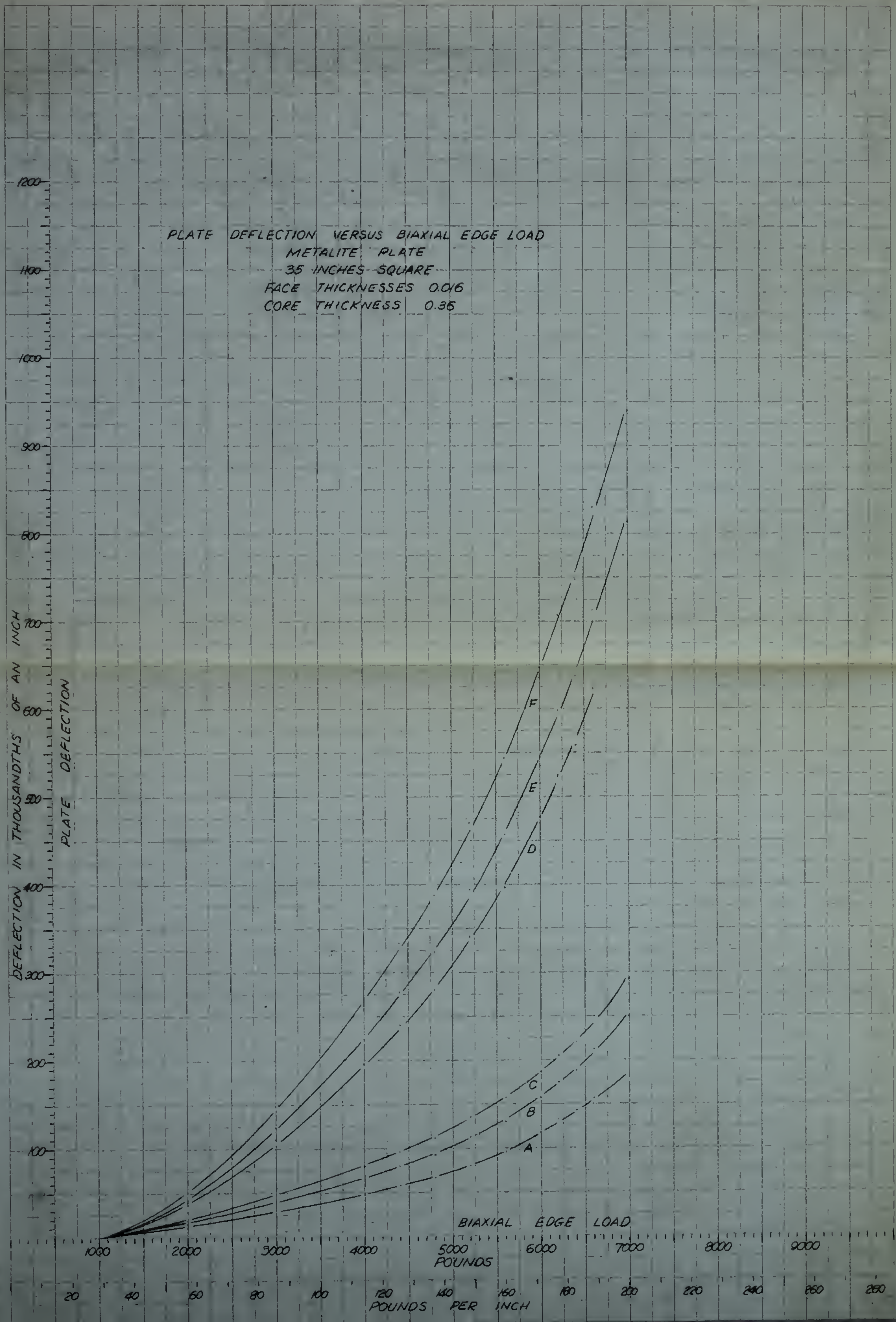


PLATE DEFLECTION VERSUS BIAXIAL EDGE LOAD
METALITE PLATE
35 INCHES SQUARE
FACE THICKNESSES 0.016
CORE THICKNESS 0.36

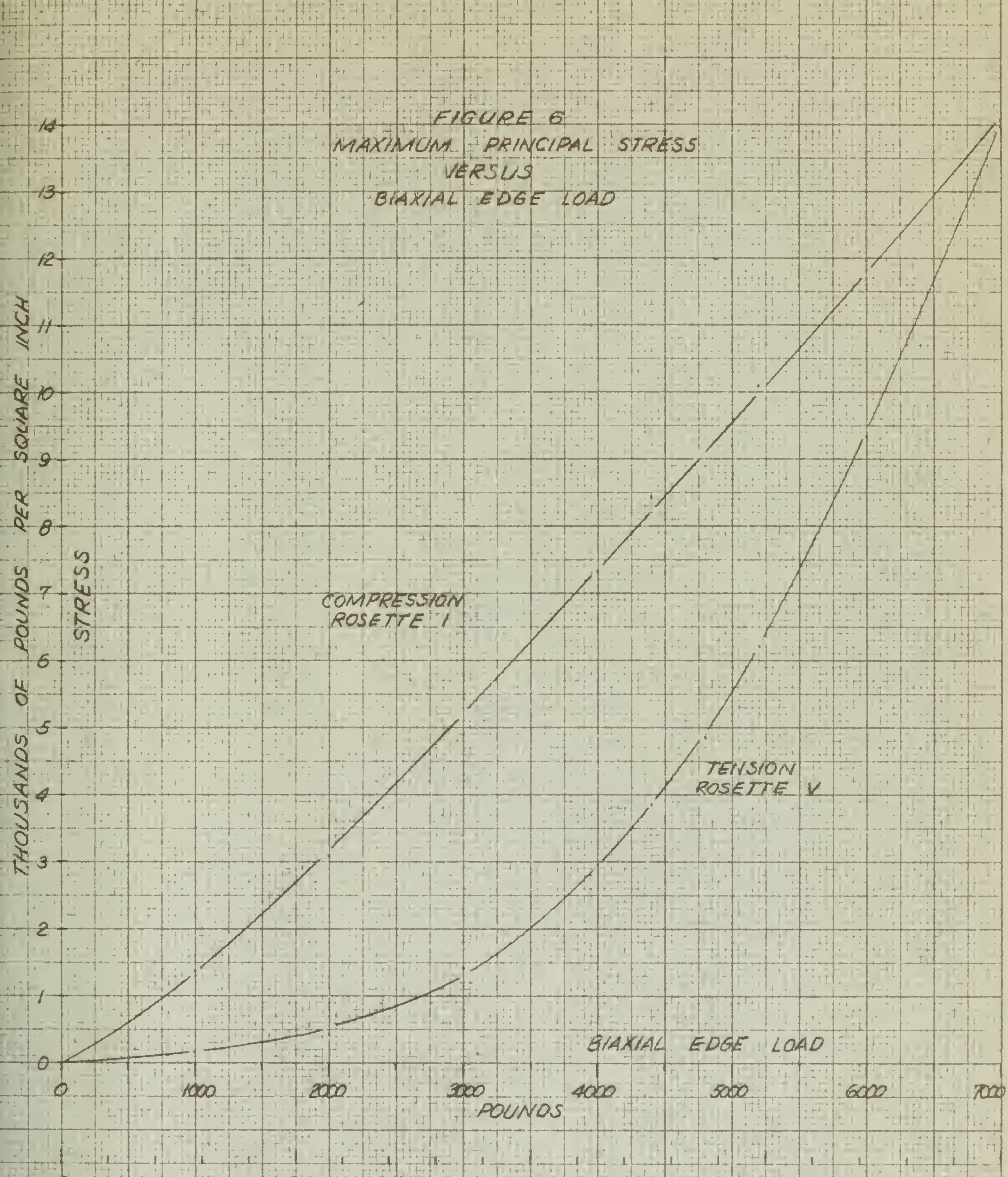


FIGURE 6
MAXIMUM PRINCIPAL STRESS
VERSUS
BIAXIAL EDGE LOAD

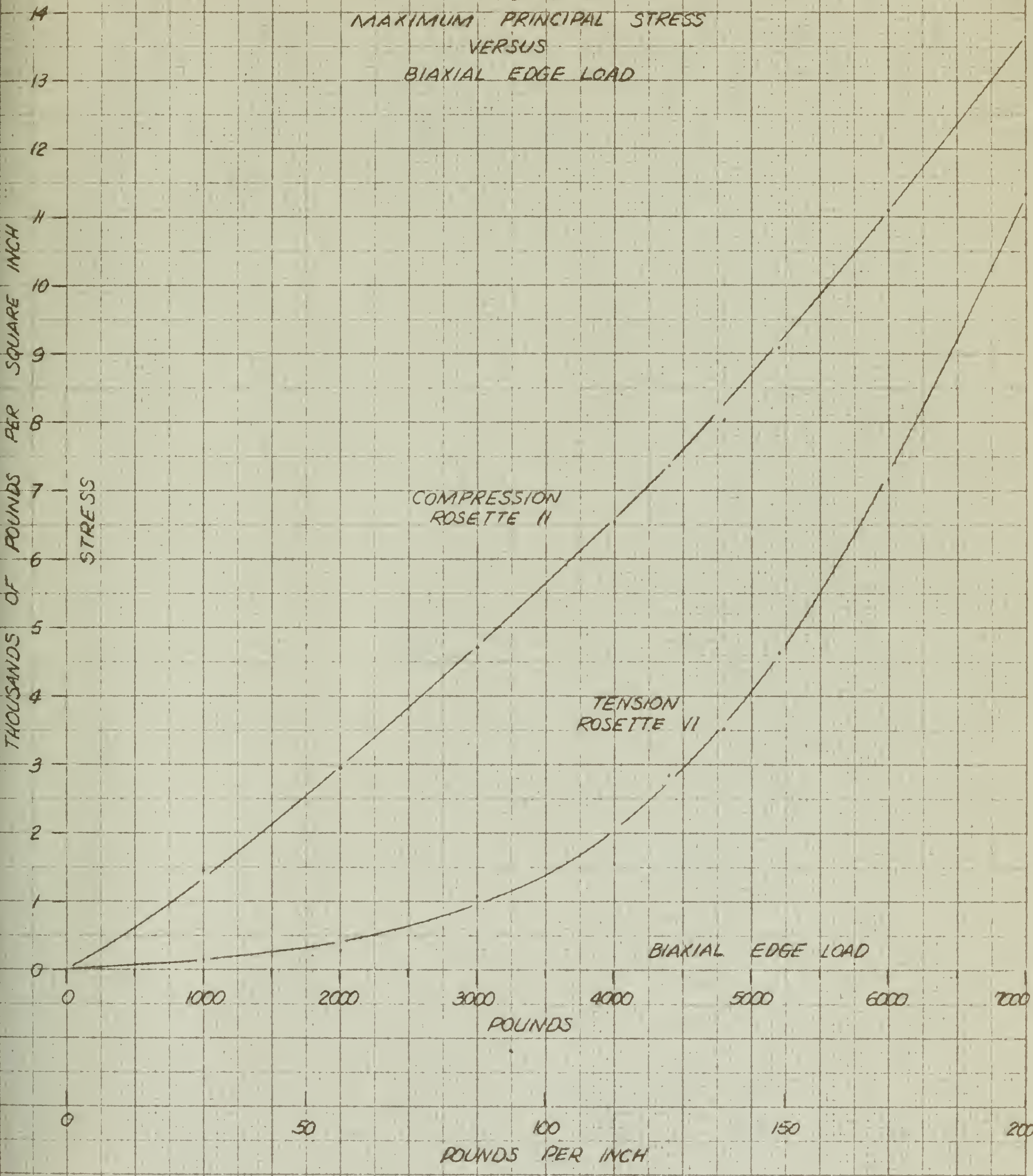


FIGURE 7
MAXIMUM PRINCIPAL STRESS
VERSUS
BIAXIAL EDGE LOAD

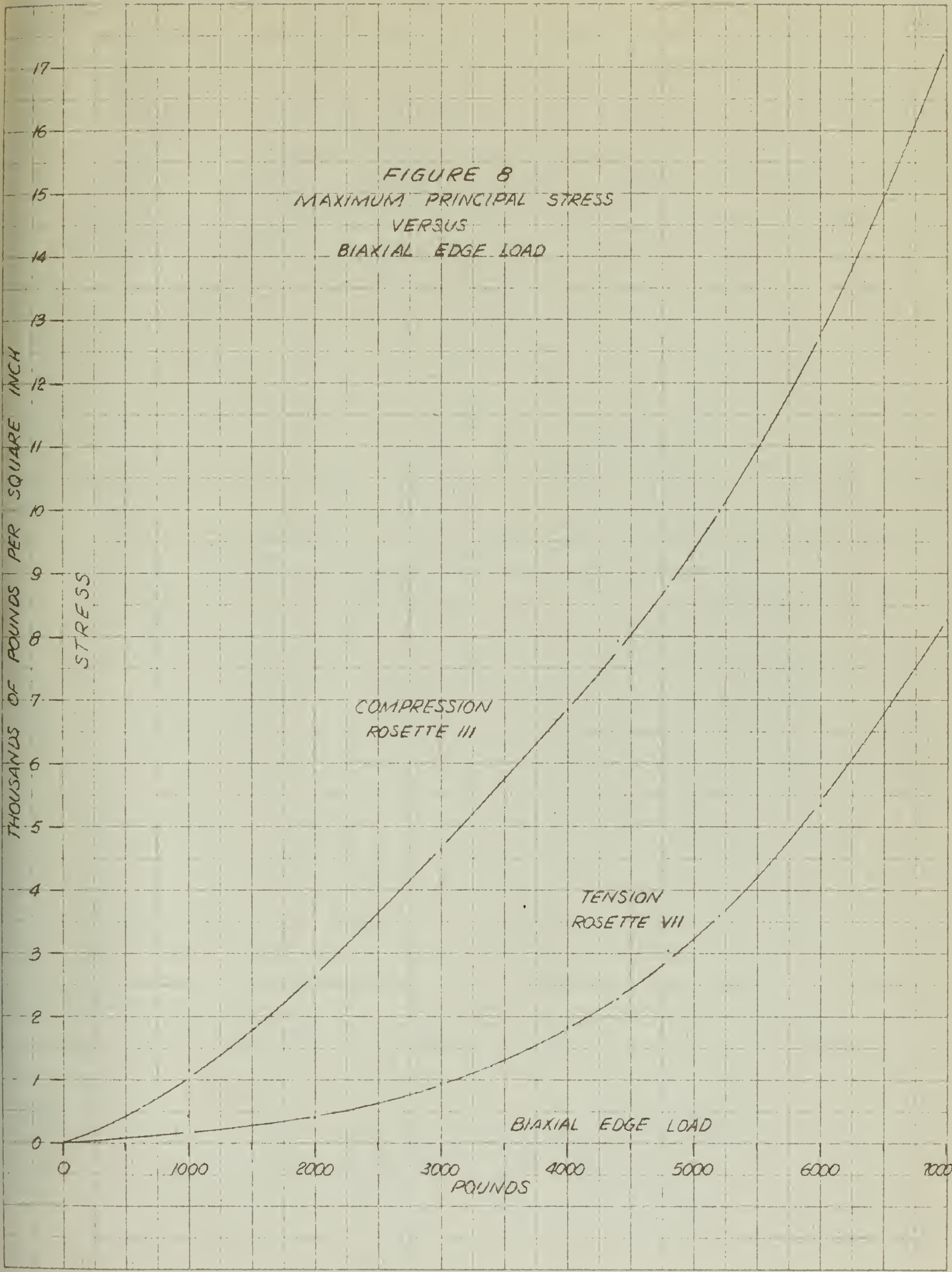


FIGURE 8
MAXIMUM PRINCIPAL STRESS
VERSUS
BIAXIAL EDGE LOAD
THOUSANDS OF POUNDS PER SQUARE INCH
STRESS
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
COMPRESSION
ROSETTE III
TENSION
ROSETTE VII
BIAXIAL EDGE LOAD
0
1000
2000
3000
4000
5000
6000
7000
POUNDS

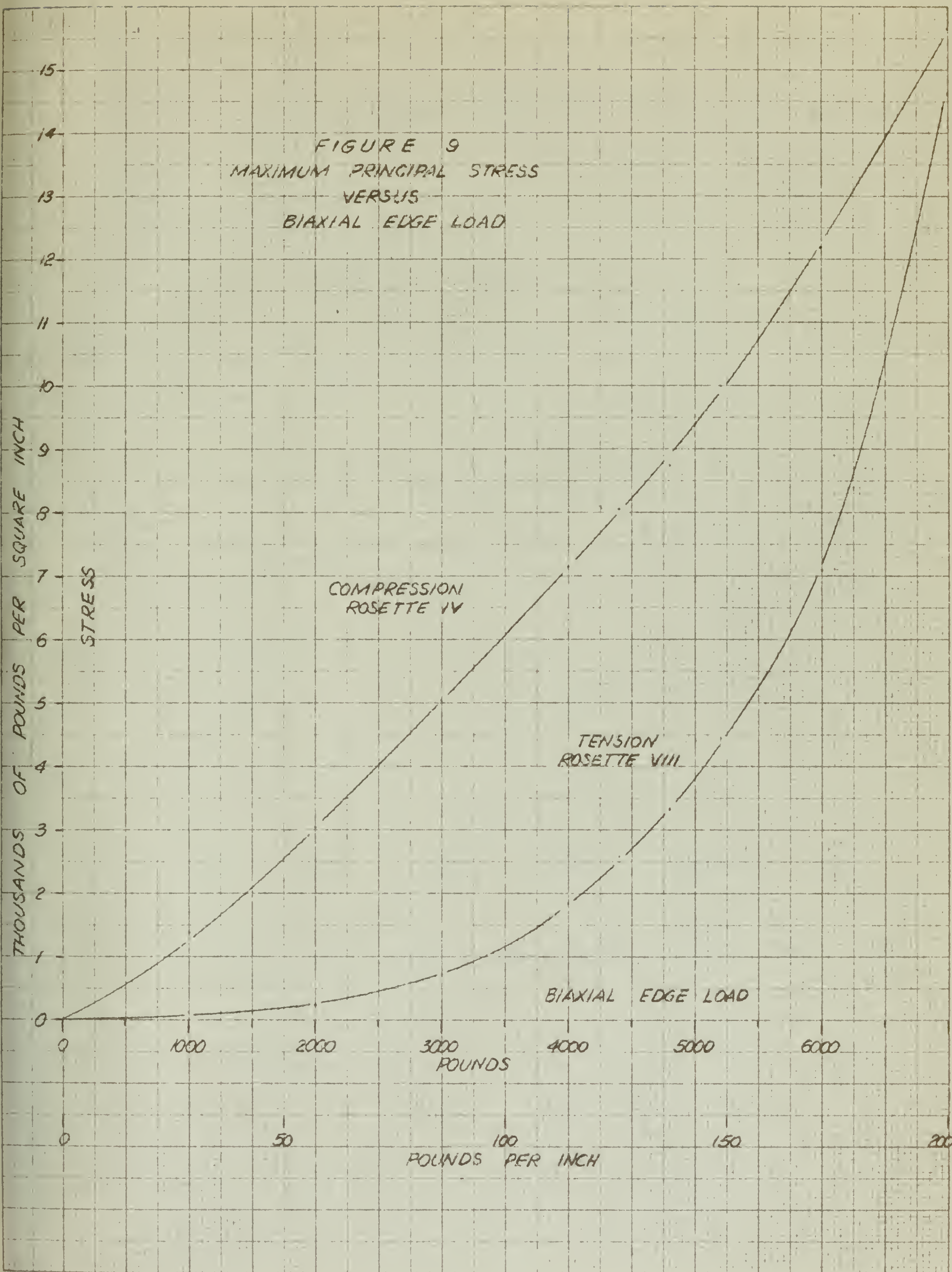


FIGURE 9
MAXIMUM PRINCIPAL STRESS
VERSUS
BIAXIAL EDGE LOAD

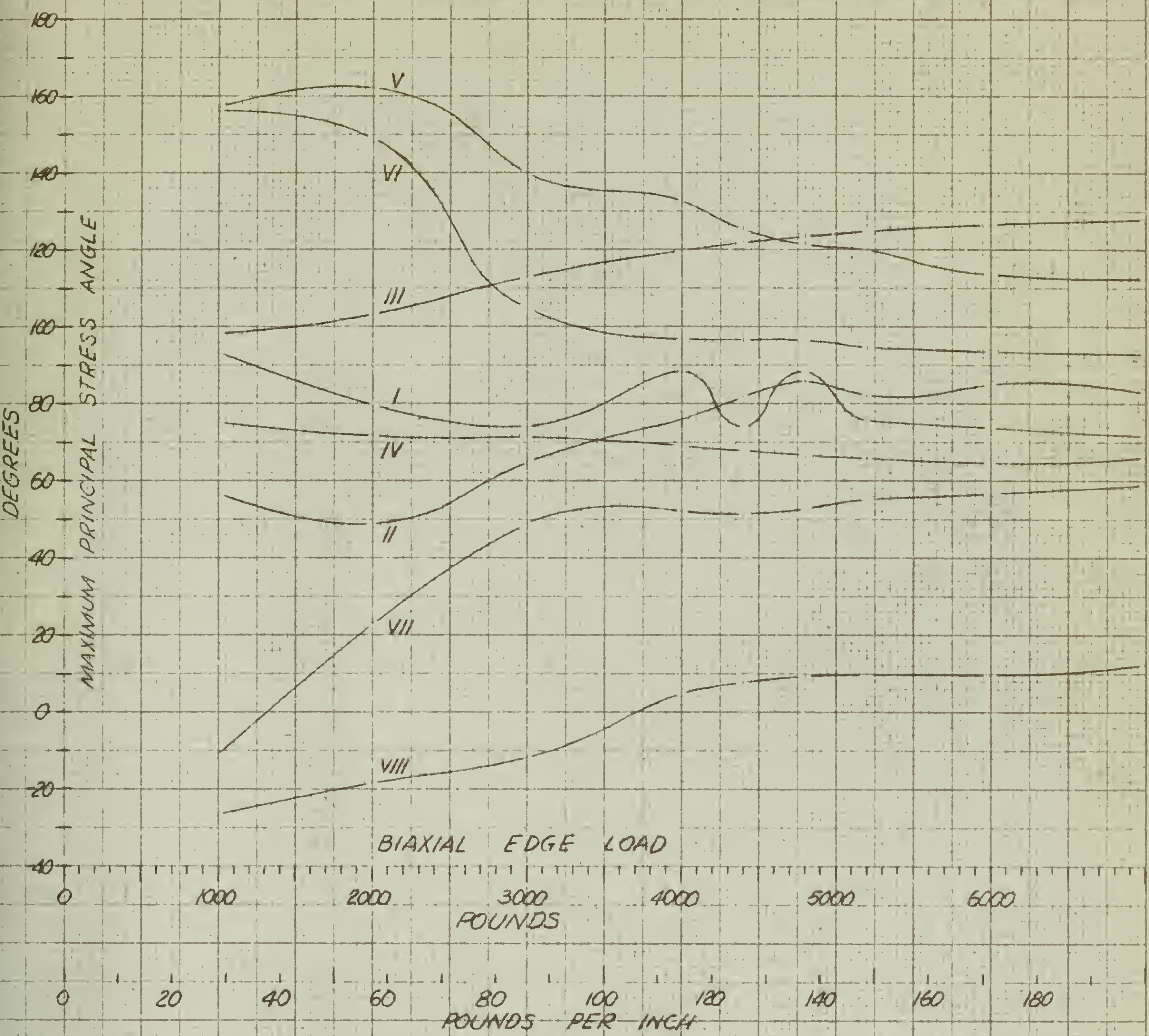


FIGURE 10
MAXIMUM PRINCIPAL STRESS ANGLE VERSUS BIAXIAL EDGE LOAD

APPENDIX A

TESTING APPARATUS
FOR
THIN PLATES
SUBJECTED TO
BIAXIAL LOADING
IN THE
PLANE OF THE PLATE
EDGES SIMPLY SUPPORTED

APPENDIX A

TESTING APPARATUS FOR THIN PLATES SUBJECTED TO BIAXIAL LOADING IN THE PLANE OF THE PLATE WITH ITS EDGES SIMPLY SUPPORTED

In an effort to achieve a device by which a thin plate could be subjected to biaxial loading in the plane of the plate with its edges simply supported, a frame and system of loading bars and blocks was designed. The frame (Figure 1) consists of a double picture frame of four by four by three-eighths inch structural steel. The two frames are separated at the desired distance by the proper length of pipe placed between the frames at a hole at each of the four corners; through the holes in the pipes and frames are bolts with nuts to hold the frames together firmly. This composite frame is to stand upright on supports on the bed of a compression loading machine. In the vertical direction the load is applied from the head and bed of the machine to the plate through a system of load-distributing bars and blocks (Figure 2) which distribute the load uniformly along the two horizontal edges of the plate; in the horizontal direction the load is applied to the vertical edges of the plate by two tension rods which apply the load through a similar system of load-distributing bars and blocks. The load-distributing bars are separated in their direction of applied load by lengths of one-quarter inch drill rod, and are positioned spacewise by a lightweight frame (Figure 5) with pipes and bolts. Along each side of, and adjacent to the plate are eight pairs of mated blocks (Figure 3a and 3b); they are held together by the proper length

of one-quarter inch drill rod. The load-side block of each pair is held in place by six bolts threaded through the angle frames (three bolts through each frame per block) in a manner such that movement of the blocks is possible only in the plane of the plate and applied load; there are ninety-six of these bolts in each frame. The plate-side block of each mated pair is toothed in order that the restraint imposed on the compression of the edge of the plate when subjected to load will be minimized.

This design allows for rotation of the edges of the plate about lines in the extended middle plane of the plate and for translation of the edges of the plate in planes parallel to the middle plane of the plate. The assembly will accommodate one size plate, a thirty-six inch square test specimen. It allows for an edge translation of approximately three-sixteenths of an inch, for an edge rotation of approximately fifteen degrees and/or a deflection at the center of the plate of approximately two inches for a one inch thick plate. For plates thinner than one inch the allowable deflection at the center increases by one-half the amount that the plate is less than one inch thick.

For plates of thickness in the order of one-half inch or less, it is necessary to modify the arrangement in that at comparatively small loads the test specimen is unstable with respect to the toothed loading blocks and will spring free of the teeth. By reducing the size of the plate and installing restraining blocks (Figure 6) this difficulty is eliminated.

Ninety six holes each frame tapped for
$\frac{1}{4}$ inch USS cap screws

Cross Section
At Mid-Span
Of Uppermost Two Angles

Double picture frame of 4 by 4 by $\frac{3}{8}$ inch structural steel angle separated at each corner by a $2\frac{1}{4}$ inch length of $\frac{5}{8}$ inch pipe and held together by a $3\frac{1}{2}$ by $\frac{1}{2}$ inch bolt with nut through each pipe and angles

LAYOUT OF
ANGLE FRAMES

DIMENSIONS : Inches
SCALE : Half Size

5/8

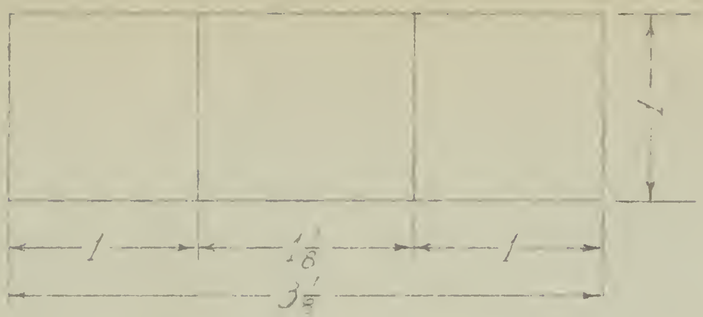
LAYOUT
OF
LOADING BARS AND BLOCKS

DIMENSIONS : Inches
SCALE : Half Size
MATERIAL : Cold Rolled Steel

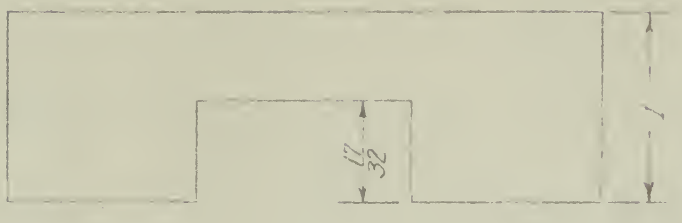
MATERIAL : Steel
Cross Section
of
Bars and Blocks
for
Horizontal Loading

FIGURE A3a

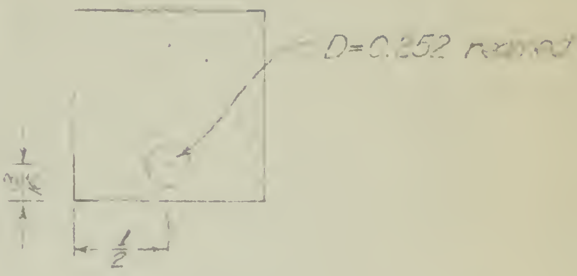
OUTER HINGED BLOCK



Bottom Plan View



Elevation View



Section View

Each pair of mated blocks connected by $4\frac{3}{8}$ inch length of one-quarter inch drill rod

Top Plan View

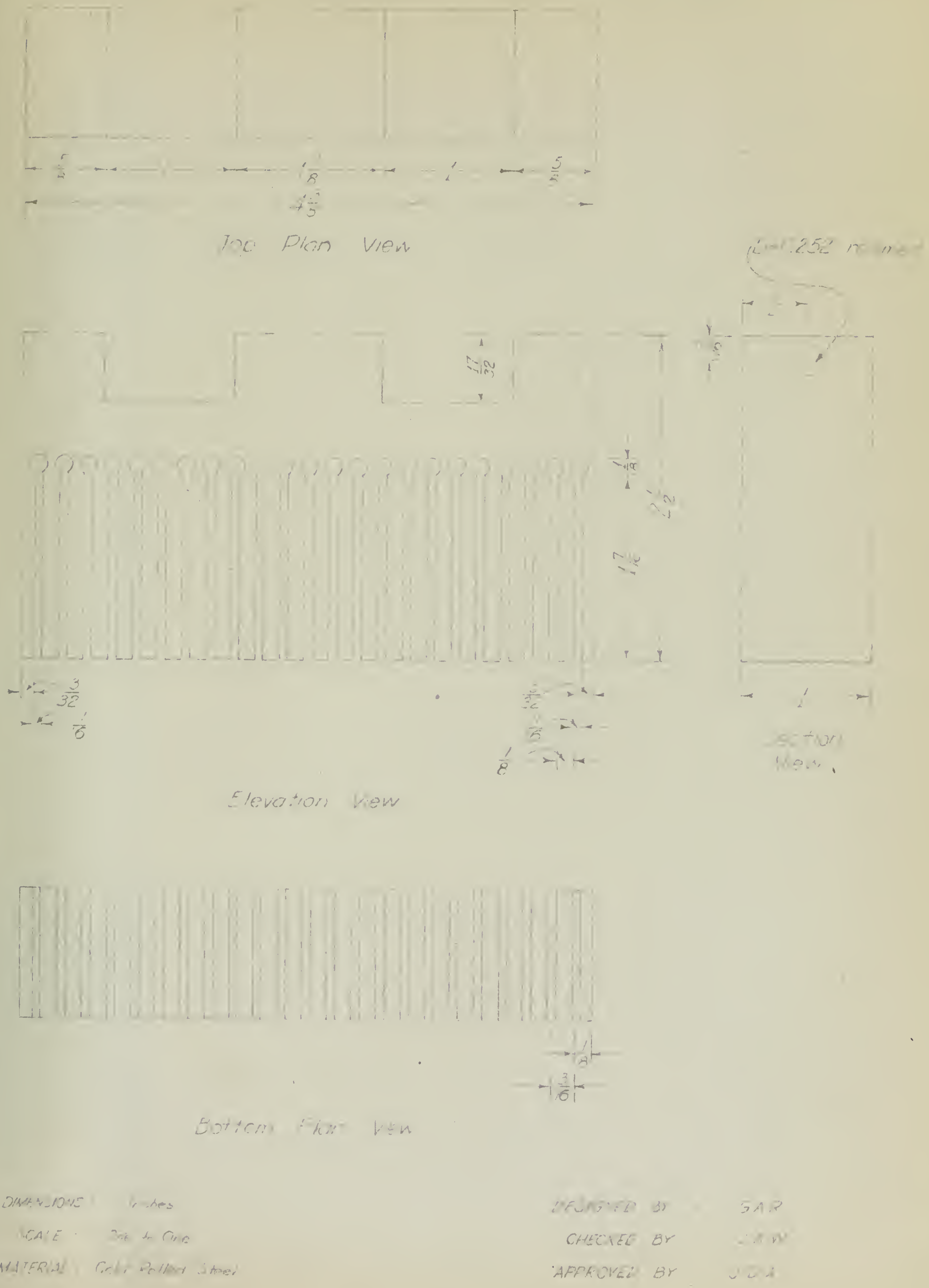
This block and toothed block to which it mates are to be cut to dimensions such that a standard free fit is obtained at contact surfaces

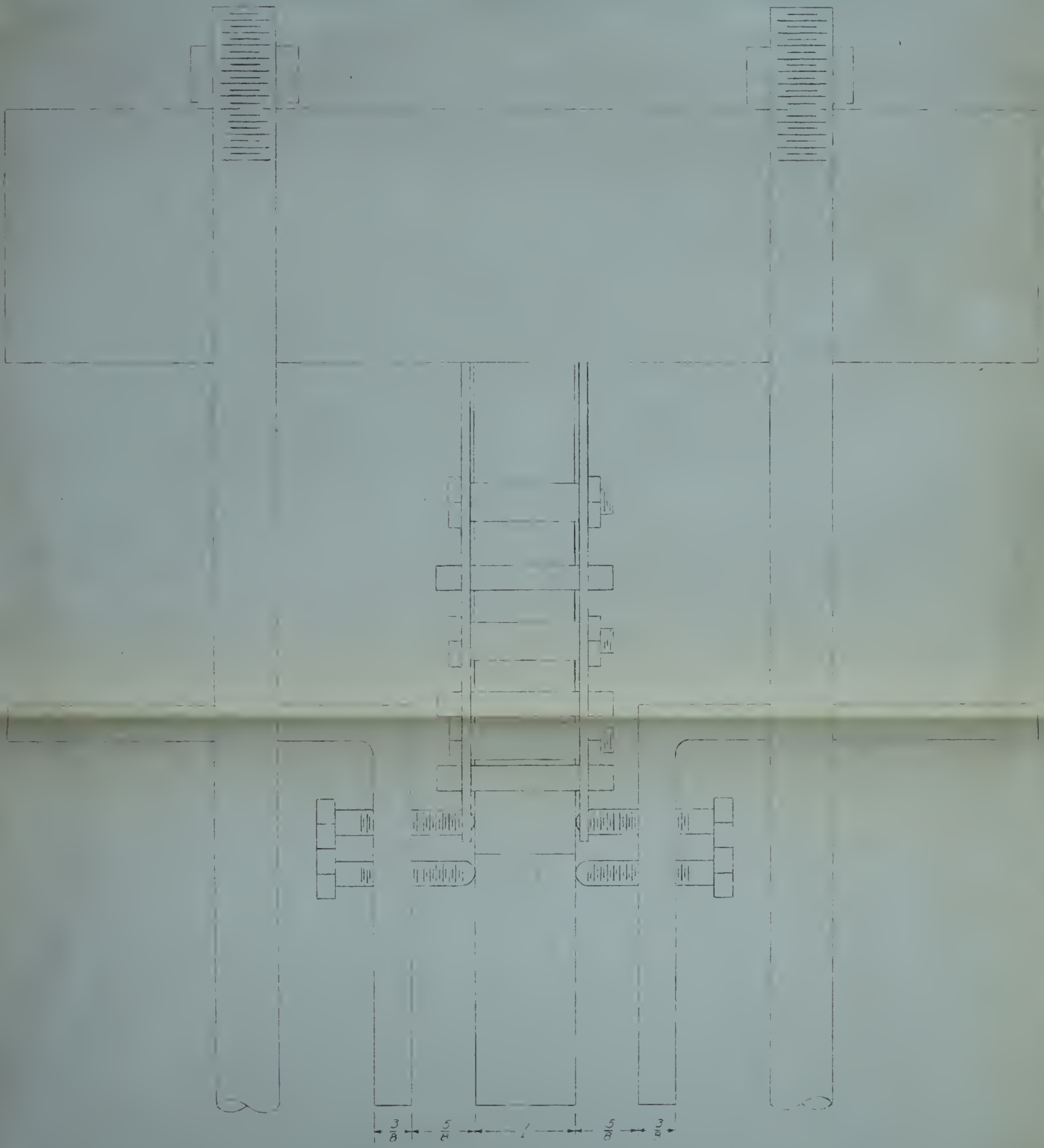
DIMENSIONS: Inches
SCALE: Full Size
MATERIAL: Cold Rolled Steel

DESIGNED BY: G.A.R.
CHECKED BY: J.A.W.
APPROVED BY: J.D.A.

FIGURE A3b

INNER TOOTHED HINGED BLOCK





Cross Section
A1
Mid-Span of Testing Frame
Illustrating
Horizontal Loading Arrangement

C.A.R.
1919

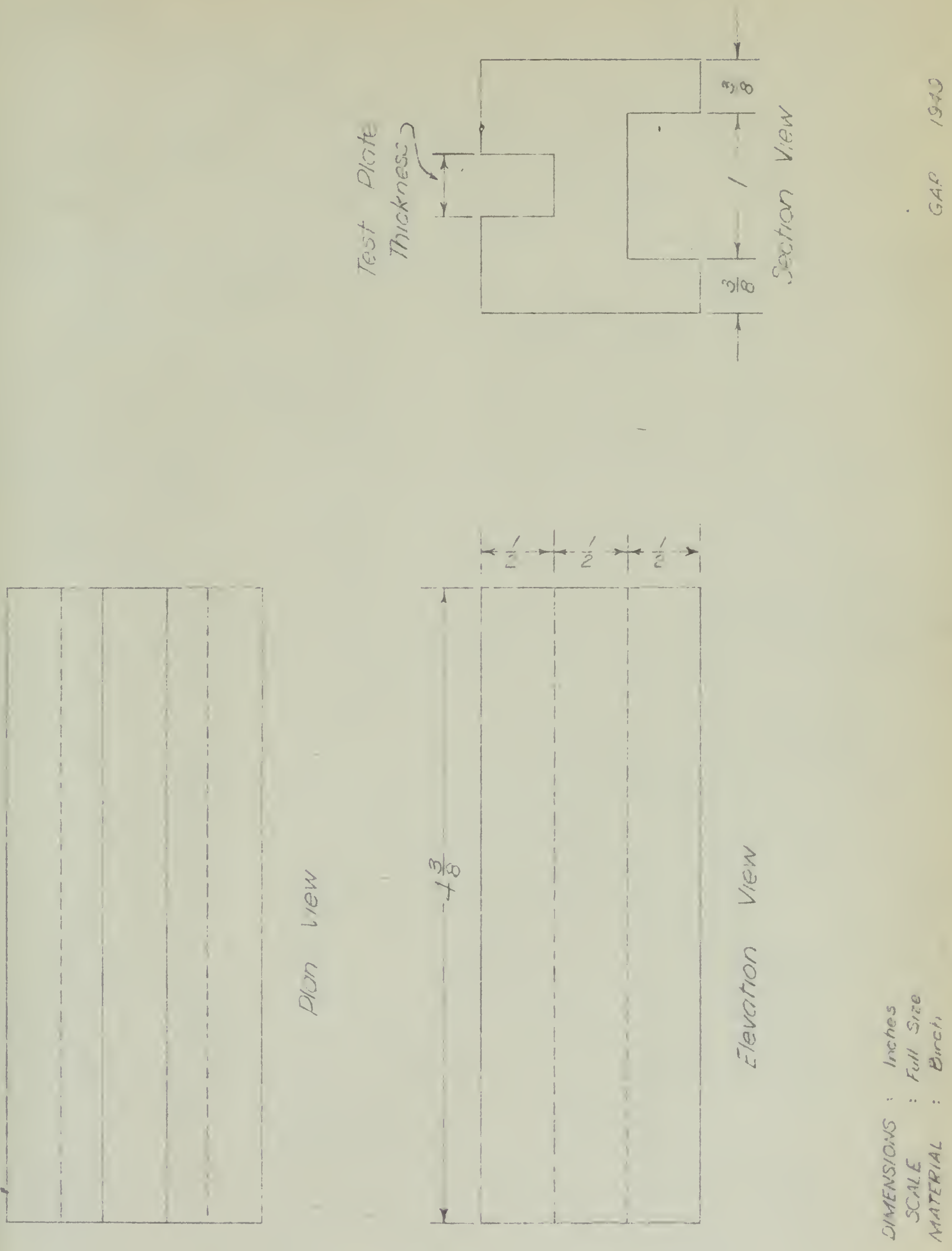
Two $\frac{1}{2}$ inch thick plates of positioning frame are separated by means of $1\frac{1}{16}$ inch lengths of $\frac{5}{8}$ inch pipe [illegible] on $\frac{1}{2}$ inch [illegible] holes which are [illegible] $\frac{1}{2}$ inch by $\frac{3}{4}$ inch [illegible] counterbored cap screws [illegible] and drill holes for $1\frac{3}{4}$ inch by $\frac{1}{4}$ inch mill roll [illegible] for 1 inch roller

DIMENSIONS : Inches
SCALE : Half Size
MATERIAL :

Layout of Positioning Frame
for Loading Bars and Rollers

FIGURE A6

PLATE POSITIONING BLOCK



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The behavior of a metalite plate when subjected to uniformly distributed loads acting in the plane of the plate.

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